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MODEL VALIDATION OF THE HYBRID EFFECT IN CARBON/GLASS HYBRID COMPOSITES

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ABSTRACT

Carbon fibre-reinforced composites typically have a failure strain of about 2%. One way to delay the failure of the carbon fibres and increase the failure strain is through fibre hybridisation [1]. By adding glass fibres for example, the apparent failure strain of carbon fibre can be increased. This synergetic effect is called the "hybrid effect" in the literature. The hybrid effect has caused confusion in the literature as soon as it was discovered by Hayashi in 1972 [2]. Initially, the synergism was attributed to differences in thermal contractions of both fibre types. Soon, it became clear that this was insufficient to explain the hybrid effect. The focus then shifted to changes in the failure development. This approach was more successful in predicting the hybrid effect, although the predictions remained qualitative [3].

Model validations of the hybrid effect are hampered by two types of experimental difficulties. Firstly, tensile tests on unidirectional carbon fibre composites are often affected by stress concentrations at the grips. This strongly reduces the measured failure strains. Hybrid composites are less prone to these stress concentrations, as the glass fibres shield the stress concentrations from the carbon fibres. This often leads to a larger measured failure strain, which could falsely lead to the conclusion of a large, positive hybrid effect. Secondly, carbon and glass fibres should be well dispersed to achieve a measurable hybrid effect, but the required preforms are difficult to obtain commercially.

This abstract proposes a new methodology for experimentally validating models for the hybrid effect. This consists of sandwiching a 30 µm thin carbon fibre ply in between glass plies (see Fig. 1). Such thin layers are required to achieve a large hybrid effect. The reference failure strain for the carbon fibre ply is also measured in a hybrid composite to avoid stress concentrations in the grips. In this case however, the carbon fibre ply is much thicker. A strength model is required to determine the minimum layer thickness to avoid a significant hybrid effect.

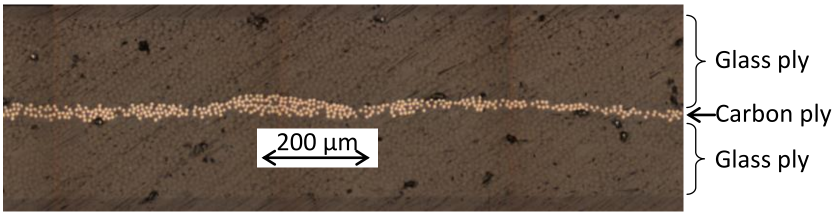

Figure 1: Cross-sectional image of the 1 ply carbon hybrid, showing the variation in carbon fibre ply thickness.

The strength model was developed for the purpose of modelling hybrid composites. It has been extensively described in Swolfs et al. [4]. Essentially, it creates a bundle of fibres and splits each of the fibres into fibre elements. A Weibull strength is assigned to each of these elements. The model then gradually increases the applied strain and tracks when the element stress exceeds the element strength. If this occurs, then the element is considered broken and stress concentrations are applied in the vicinity of the fibre break. The very local load sharing rule is used, meaning only the nearest neighbours carry stress concentrations. The model is interrupted when a critical cluster develops in the carbon fibres, which indicates failure of the carbon fibre layer.

Four different layups were modelled and tested experimentally. These layups consist of 1, 2, 3 and 4 plies of carbon fibre, corresponding to carbon fibre layer thicknesses ranging from 30 µm to 120 µm. This yields a failure strain of 2.2% for the 1 ply carbon hybrid, which corresponds to a hybrid effect of 16%. Even though the model underestimates this failure strain, it does capture the correct trend for decreasing failure strain with increased number of carbon fibre plies. Including the effect of residual stresses would bring the modelling predictions closer to the experimental results.

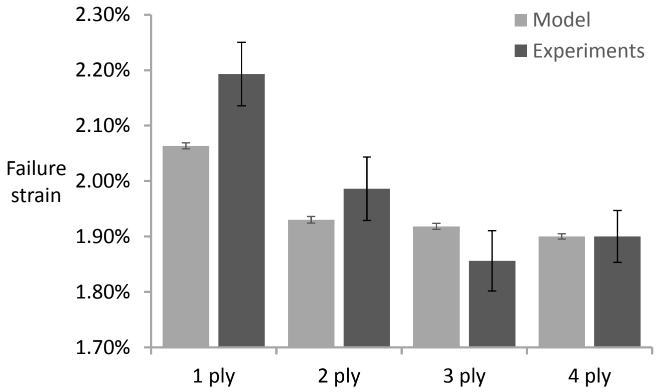

Figure 2: Comparison between model and experimental predictions of the failure strain.

This work uses a new and reliable methodology for measuring the hybrid effect. By combining this with a strength model for hybrid composites, the hybrid effect was experimentally validated. Further improvements would require an accurate determination of the Weibull distribution of the carbon fibres, which is the most vital input parameter in the model.

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